NATIONAL BUREAU OF STANDARDS REPORT

7591

The Transition Zone of the Visual Approach Slope Indicator As a Function of Beam Chromaticities

By
Andrew C. Wall

NBS

U. S. DEPARTMENT OF COMMERCE
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0201-30-02303 August 1962 7591

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Prepared For
Aviation Facilities Service
Federal Aviation Agency
Washington 25, D. C.

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

The Transition Zone of the Visual Approach Slope Indicator As a Function of Beam Chromaticities

1. PURPOSE

This report gives the results of an analysis of observations made by a group of observers viewing the projected beam of a Visual Approach Slope Indicator. The individual observer was required to indicate his interpretation of the color of the beam (that is, white, red, or pink) when filters of different chromaticities were used and when the elevation angle of the beam was varied.

2. CHARACTERISTICS OF EQUIPMENT TESTED

2.1 General

The Visual Approach Slope Indicator (VASI) used in the test was an off-the-line unit manufactured by Sylvania Electric Products Inc., Ipswich, Massachusetts. The indicator projects a bicolor beam in such a manner that, if the beam is swept slowly upward, an observer in the beam a few hundred feet or more from the unit will see the beam change from white through several shades of pink to red. The pink area is designated as the transition zone. The unit is described more fully in NBS Report 7419. The VASI unit was mounted on the goniometer described in Section 2.1b of NBS Report 7410. The unit was lamped with three 6.6-ampere, 300-watt lamps which were controlled by a continuously variable autotransformer.

2.2 Filters

Four types of filters[1/] were used for the test and are shown in table I. The spectral transmittance curve of a representative color-correcting-white filter is shown in figure 1.

[1/] The filters are designed to serve as horizontal spread lenses and to alter the chromaticities of the light beams.

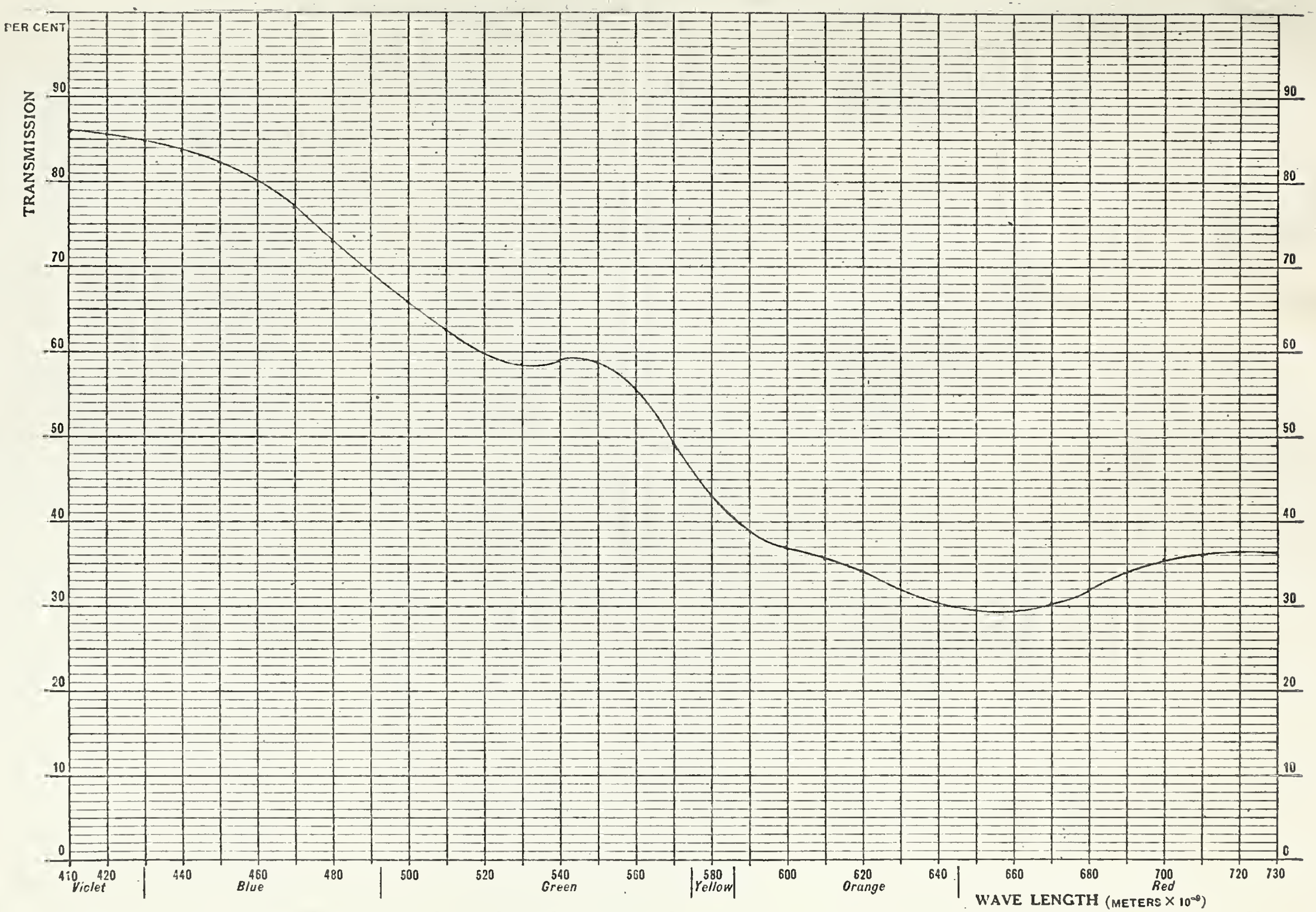

Figure 1. Spectral transmission curve of a representative sample of the type 289 color-correcting-white filter.

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Table I. Filters Used in the VASI for the Observations

Kopp Glass Type	Designation	Transmittance	Chromaticity Coordinates x	y	z
#625	Aviation-Red	0.205	0.683	0.317	0.0002
Clear	Aviation-White	0.893	0.448	0.408	0.144
#635	Highway-Crossing-Red	0.149	0.699	0.301	0.0001
#289	Color-Correcting[2/]-White	0.480	0.375	0.396	0.229

2.3 Photometric Characteristics

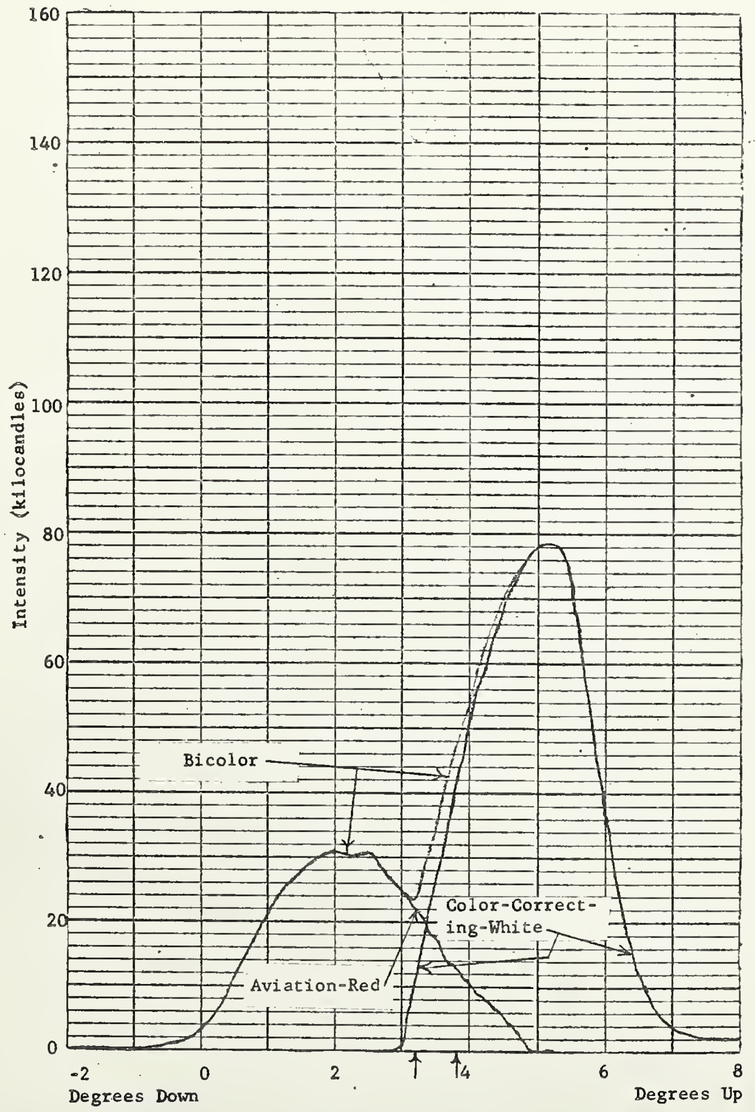
Intensity distribution measurements were made using the four filters mounted in pairs in a simulated VASI (described in NBS Report 7419). The photometric distance was 30 meters. A goniometer reading of 0.0° indicates the goniometer reference plane. The position of the VASI slot was adjusted for optimum performance. The filters were allowed to heat up sufficiently to stabilize their transmittance before the traverses were made. The traverses were made for each filter combination: (a) of the bicolor beam; (b) of the red segment with the white filter blocked; and (c) of the white segment with the red filter blocked. Intensity distribution curves of the VASI with each of the four possible filter combinations are shown in figure 2.

3. PROCEDURE FOR VISUAL OBSERVATIONS

3.1 General

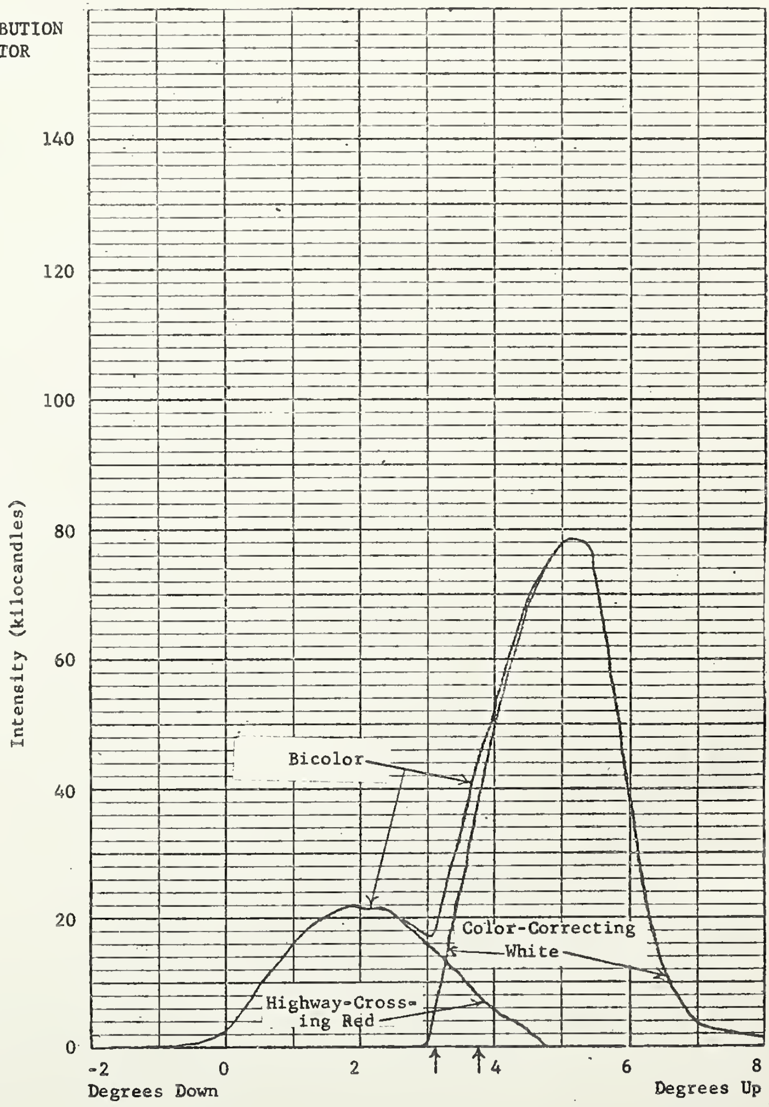
Several sets of preliminary observations were made of the VASI performance under various conditions and with various heterogeneous groups of observers. On the basis of the data accumulated, it was decided to make the observations needed for all possible two-color combinations (four) of the two red and the two white filters on the same day and with the same observers being used throughout. The procedure decided upon and described below was chosen as the most valid from amongst the many that were tried. The first two sets of observations, described in Sections 3.2(1) and 3.2(2), were made between 10:00 and 11:00 a.m. EDT, on July 5, 1962; the observations described in Sections 3.2(3) and 3.2(4) were made between 3:00 and 4:00 p.m. of the same day. The sun was bright during both periods of observation; the background was the north side of a brick building. Eight observers were used, stationed in the open air approximately 750 feet from the VASI unit.

[2/] This filter increases the color temperature of the light to about 4000°K. The values shown in table I are for a representative sample from 20 submitted.



VERTICAL INTENSITY DISTRIBUTION
TRIADS OF A VASI SIMULATOR

Horizontal Angle of
Traverse: 0.0°
Lamp: One 300-Watt,
6.6 Ampere PAR Type.
Filters: As Indicated
Current: Rated
Arrows on Axes of
Abscissas Indicate
Visual Transition
Zone (See Section 2.1)



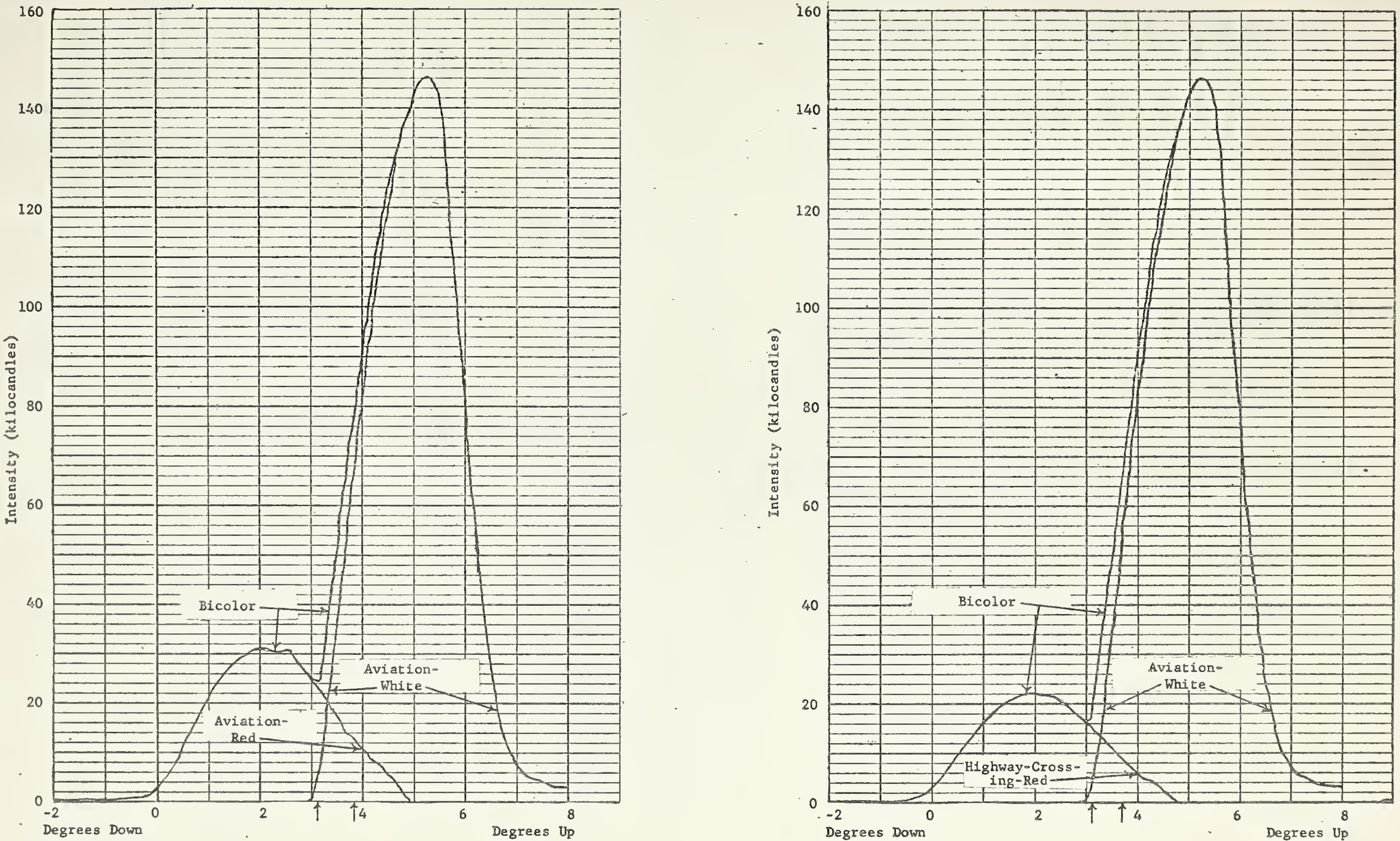

160
140
120
100
80
60
40
20
0
Intensity (kilocandles)
-2
0
2
4
6
8
Degrees Down
Degrees Up
Bicolor
Aviation-White
Aviation-Red
160
140
120
100
80
60
40
20
0
Intensity (kilocandles)
-2
0
2
4
6
8
Degrees Down
Degrees Up
Bicolor
Aviation-White
Highway-Crossing-Red

Figure 2

3.1.1 Reference for Elevation Angles

3.1.1.1 Observation Angles. All elevation angles in this test are measured from the goniometer reference plane and are taken as positive when the line of sight of the observers is above this plane.

3.1.1.2 Elevation Angle Adjustment of Unit. Adjustment of the elevation angle of the unit with respect to the goniometer reference plane was made using the "leveling device" supplied with the unit (described on FAA Drawing C556-6). In use this device is positioned by the transition bar and the bottom of the slot. It is intended to be used in adjusting the elevation angle of the unit to a predetermined value. The leveling device incorporates a calibrated cam showing the angle of the axis of the device above the horizontal reference. Much of the literature of VASI refers to a "setting angle" of a unit, which is defined as the lowest angle of an observer's eye at which he can first see white light in the red zone. (To determine this angle, it is convenient to block the red light at the source or at the observer's eye by a green filter.) See figure 3. As will be shown later, it was found in this test that the angle of the axis of the leveling device was essentially the setting angle of the VASI unit.

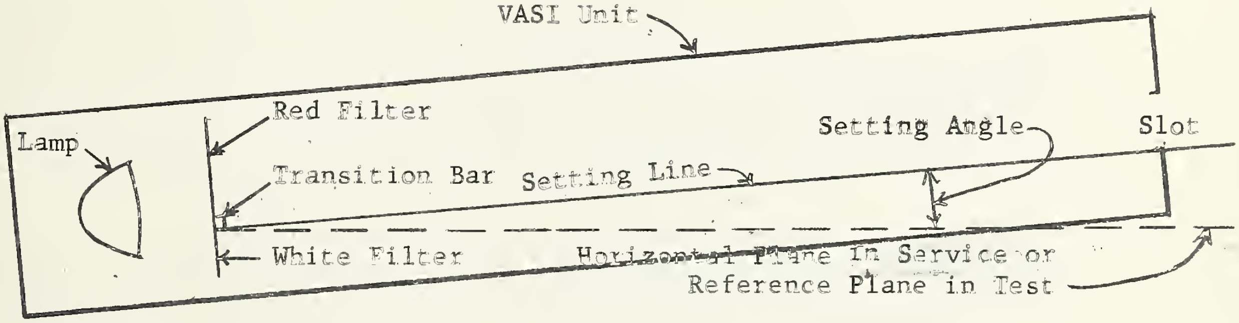


Fig. 3. The setting angle of a VASI unit is the lowest angle above horizontal of an observer's eye at which he can see white light.

The leveling device also incorporates a "high-low" rotating section. With a "high" setting the device produces a setting angle 0.25° greater than the angle indicated on the dial. With a "low" setting the device produces a setting angle 0.25° less than the dial setting. (This dual-positioning feature produces a 0.50° separation between the elevation angles of the upwind and downwind units in a service installation and is presumably intended to position the glide path on the angle at which the device is set.)

The goniometer on which the VASI unit was set had, initially, its reference plane horizontal and the VASI unit was adjusted using the leveling device set at 2.75°, with the rotating section on "high." The resulting setting angle should therefore have been 3.00° above the goniometer reference plane.

3.2 Observational Procedure Used and Filter Combinations Tested.

(1) Filter Combination #1. This filter combination is specified for the VASI unit and can be considered as the reference standard for the evaluation of other filter combinations. The filters used were aviation-red and aviation-white. The VASI unit was initially placed at such an angle that, with 6.6 amperes through the lamps, the observers were in the red sector of the beam just below the edge of the pink sector. For the second position, the beam was lowered 0.20°; for the third position the beam was raised 0.10°; this sequential pattern was repeated until the observers were in the white sector of the beam, just beyond the edge of the pink segment. The range of elevations was 1.20°, encompassing 23 positions in all.

The sequential pattern was then reversed, giving 23 positions from white to red. Each elevation was therefore presented to the observers four times. The lamp current was reduced to 5.2 amperes and the same sequential pattern of 46 positions was again presented. With the lamp current set at 4.1 amperes, the same pattern was again followed, giving a total of 138 position-presentations to the observers.

(2) Filter Combination #2. Color-correcting-white and aviation-red filters were used as combination #2; the same sequential pattern of position-presentations was used as described in Section (1), giving a total of 138 responses per observer for this filter combination.

(3) Filter Combination #3. Highway-crossing-red and color-correcting-white filters were used for this part of the test. During the performance of this part of the test it became evident that there was a possibility that the observers were becoming more interested in predicting a response from the sequential pattern being used than in noting fine differences in color. The pattern was, however, continued through the 138 position-presentations.

(4) Filter Combination #4. This combination of filters was highway-crossing-red and aviation-white. As with the previous combinations, a total of 138 positions were presented to the observers, but the sequence pattern was broken and the angles were set in a pseudo-random order. Each position was presented four times.

4. RESULTS OF VISUAL OBSERVATIONS

The distribution of the "pink" responses to the stimuli as a function of the angle of elevation of the VASI unit gave indication of being a normal distribution. See figure 4. Two sets of values were then given the chi-square test for fit to a normal distribution. Filter combination #2 at 6.6 amperes gave a probability P equal to 0.93 (the chi-square value was 1.93 for six degrees of freedom); filter combination #1 at 5.2 amperes then gave a P equal to 0.84 (the chi-square value was 3.40 for seven degrees of freedom).

The probability P is interpreted to mean that when the population is normal, deviations as much as or more than those obtained here may occur 93 or 84 times out of a hundred by chance. Therefore, on the basis of the high probability of fit of the two cases, an assumption of a normal distribution was made for each set of responses and the data were analyzed accordingly.

A weighted mean angle was determined from the angular positions recorded by the observers as being "pink" responses. The standard deviation of the responses (in angular notation) from the center of the pink zone (the center defined here as the mean angle of the pink responses) was then determined. The width of the pink zone is defined as ±1.96 standard deviations, a range encompassing 95% of all cases in a normal distribution. The results of the study are shown in Table II.

DISTRIBUTION OF "PINK" RESPONSES COMPARED TO A NORMAL DISTRIBUTION CURVE

Number of Observers: 8 at 750 Feet. Lamps: 3 300-Watt at 6.6 Amperes.
Spread Lenses: Aviation-Red, Color-Correcting White

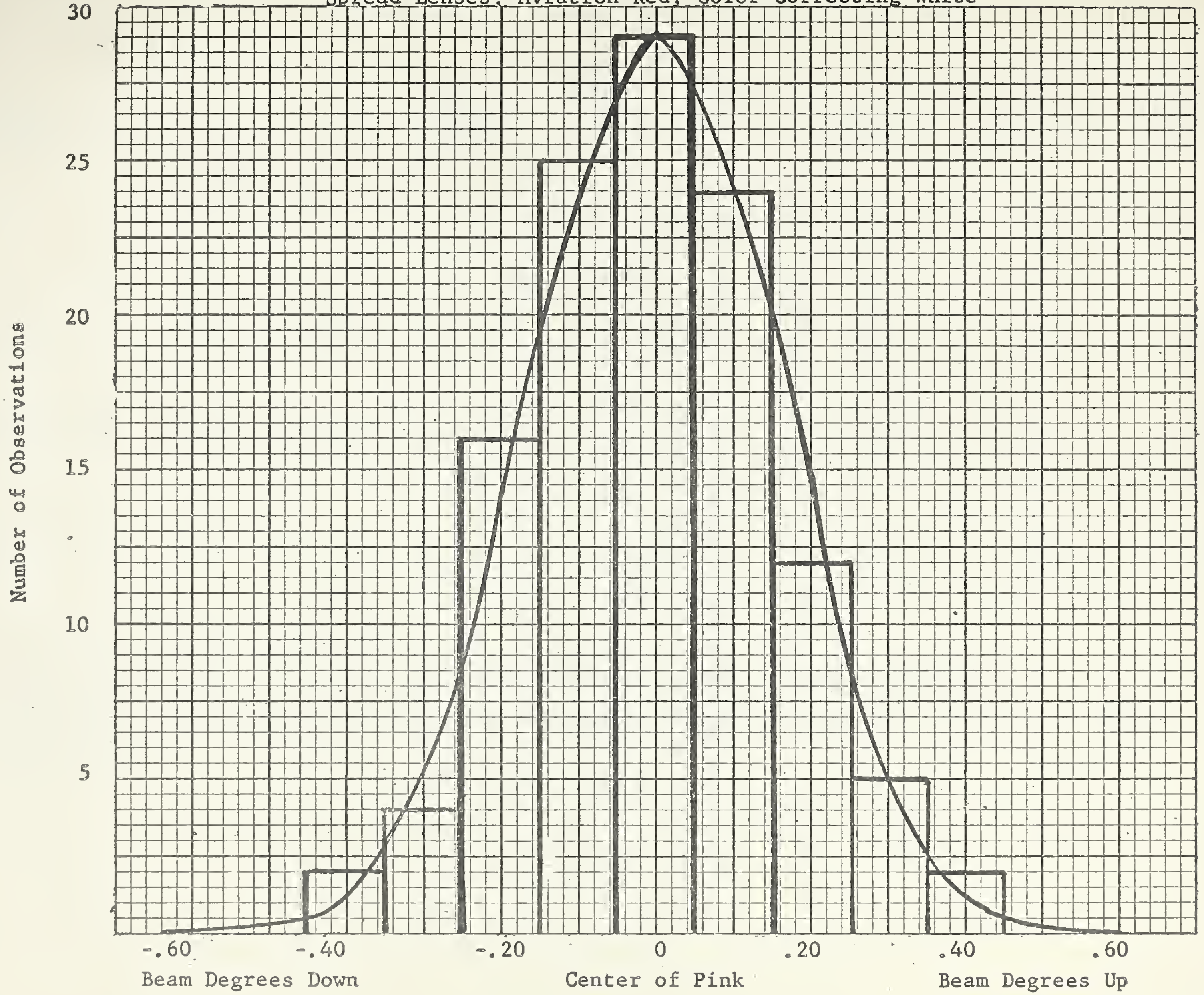


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Figure 4

Table II. Statistical Analysis of Responses Recorded as "Pink"

Filter Used		Lamp Current (Amperes)	Number of "Pink" Responses 1/	Elevation 2/ (Degrees)	Standard Deviation (Degrees)	Width of Pink Zone 3/ (Degrees)
Red	White					
Aviation	Aviation	6.6	124	3.45	0.18	0.71
		5.2	141	3.56	0.18	0.71
		4.1	138	3.58	0.17	0.67
Aviation	Color-Correcting	6.6	119	3.51	0.16	0.63
		5.2	110	3.56	0.16	0.63
		4.1	121	3.61	0.17	0.67
Highway-Crossing	Color-Correcting	6.6	113	3.43	0.16	0.63
		5.2	117	3.49	0.15	0.59
		4.1	114	3.56	0.16	0.63
Highway-Crossing	Aviation	6.6	127	3.40	0.15	0.59
		5.2	130	3.45	0.16	0.63
		4.1	147	3.50	0.18	0.71

1/ From a total of 368 observations.

2/ Of the center of the pink zone as determined by the mean of the "pink" responses.

3/ Defined here as ±1.96 standard deviations, a range encompassing 95% of all cases in a normal distribution.

5. ANALYSIS OF DATA

5.1 Photometry.

Selected luminous intensities and some relations between them are shown in table III.

Table III. Peak Luminous Intensities of a Simulated VASI and Their Ratios.

Filter Used	Peak Intensity (Kilocandles)	Intensity Ratio as Compared With Aviation-Red	Intensity Ratio as Compared With Highway-Crossing-Red
Aviation-Red	31	-	-
Aviation-White	146	4.72	6.64
Highway-Crossing-Red	22	-	-
Color-Correcting-White	79	2.55	3.59

5.2 Transition Zone.

The photometric transition zone can be obtained from each triad of figure 2. It is that portion of the distribution which contains a measurable amount of both red and white light. (However, only the central portion of this zone, the visual transition zone, looks pink to the observer.) Luminous intensities within the photometric transition zone for one setting of current are shown in table IV. The vertical lines indicate the extent of the visual transition zones for the filter combinations used.

Table IV. Luminous Intensities Within the Photometric Transition Zone at 6.6 Amperes Lamp Current

<table>
<tr><th rowspan="3">Elevation Angle
(degrees)</th><th colspan="12">Intensity</th></tr>
<tr><th colspan="3">Filter → Highway-Crossing-Red</th><th colspan="3">Aviation-Red</th><th colspan="3">Color-Correcting-White</th><th colspan="3">Aviation-White</th></tr>
<tr><th colspan="3">(kilocandles)</th><th colspan="3">(kilocandles)</th><th colspan="3">(kilocandles)</th><th colspan="3">(kilocandles)</th></tr>
<tr><td>2.95</td><td></td><td>16</td><td></td><td></td><td>24</td><td></td><td></td><td>-</td><td></td><td></td><td>-</td><td></td></tr>
<tr><td>3.05</td><td></td><td>15</td><td></td><td></td><td>23</td><td></td><td></td><td>6</td><td></td><td></td><td>-</td><td></td></tr>
<tr><td>3.15</td><td rowspan="6">with aviation-white*</td><td>14</td><td rowspan="7">with color-correcting-white</td><td rowspan="7">with aviation-white</td><td>22</td><td></td><td rowspan="7">with highway-crossing-red</td><td>11</td><td></td><td rowspan="7">with aviation-red</td><td>8</td><td rowspan="6">with highway-crossing-red</td></tr>
<tr><td>3.25</td><td>13</td><td>21</td><td rowspan="6">with color-correcting-white</td><td>16</td><td rowspan="6">with aviation-red</td><td>16</td></tr>
<tr><td>3.35</td><td>12</td><td>19</td><td>21</td><td>25</td></tr>
<tr><td>3.45</td><td>11</td><td>18</td><td>26</td><td>34</td></tr>
<tr><td>3.55</td><td>10</td><td>16</td><td>31</td><td>44</td></tr>
<tr><td>3.65</td><td>9</td><td>14</td><td>36</td><td>54</td></tr>
<tr><td>3.75</td><td></td><td>8</td><td>13</td><td>41</td><td>64</td><td></td></tr>
<tr><td>3.85</td><td></td><td>7</td><td></td><td></td><td>12</td><td></td><td></td><td>46</td><td></td><td></td><td>74</td><td></td></tr>
<tr><td>4.05</td><td></td><td>5</td><td></td><td></td><td>9</td><td></td><td></td><td>56</td><td></td><td></td><td>90</td><td></td></tr>
<tr><td>4.25</td><td></td><td>4</td><td></td><td></td><td>7</td><td></td><td></td><td>62</td><td></td><td></td><td>106</td><td></td></tr>
<tr><td>4.45</td><td></td><td>3</td><td></td><td></td><td>5</td><td></td><td></td><td>68</td><td></td><td></td><td>118</td><td></td></tr>
<tr><td>4.65</td><td></td><td>1</td><td></td><td></td><td>3</td><td></td><td></td><td>74</td><td></td><td></td><td>130</td><td></td></tr>
<tr><td>4.85</td><td></td><td>-</td><td></td><td></td><td>-</td><td></td><td></td><td>77</td><td></td><td></td><td>138</td><td></td></tr>
</table>

* The vertical lines indicate the extent of the visual transition zones associated with the various red-white combinations.

5.3 Correlation Between Observations and Photometry.

A sample correlation between the data obtained by photometric and observational methods is shown in table V.

Table V. Relations Between Various Angles of Elevation As Set and As Observed.*

	Determined Experimentally	
Design glide path from leveling device	2.75° - high (set)	
Setting angle (design)	3.00°	
Setting angle (from test)	3.0°	(from fig. 2)
Bottom of visual pink	3.10°	(from table IV)
Center of visual pink	3.45°	(from table II)

*Using aviation-red and aviation-white filters; lamp at 6.6 amperes.

With the device still set at 2.75° and the rotating section on "low," the other values shown in table V would all be reduced by 0.50°. The resulting glide path determined would then lie midway between the centers of the two visual pink zones, or at 3.20°. The glide path as determined in this test and with the equipment used is therefore approximately one-half degree above the angle indicated by the leveling device.

6. CONCLUSIONS

(1) The color temperature of the lamps affects both the elevation angle of the pink zone (systematically) and the width of the pink zone (randomly) but the changes are small.

> The increase in elevation of the pink zone with the decrease in current through the lamps (with a consequent decrease in both the intensity and the color temperature of the lamps) is of the order of 0.05° between adjacent current settings and is significant. (The probability is less than 0.005 that the negative correlation is due to chance.)

(2) The chromaticity of the filters also affects both the elevation angle of the pink zone (systematically) and the width of the pink zone (randomly). But, as before, the changes are small.

> The substitution of the color-correcting-white for the aviation-white filters consistently raised the elevation of the pink zone, the range being from slightly more than 0.0° to 0.06° with an average slightly less than 0.04°. The substitution of the highway-crossing-red for the aviation-red filters consistently lowered the elevation of the pink zone, the range being from 0.05° to 0.11°, with an average of slightly more than 0.07°.

(3) It is noted that of the 119 "pink" responses recorded for filter combination #2 at 6.6 amperes (as an example), the range was from 9 responses (from an observer who has been working with aviation lighting for several years) to 25 responses (from an observer who had heard of aviation-red as a color designation for the first time at the time of the tests.) This wide range of responses suggests that the pink zone is narrower for some observers than for others.

(4) The axis of the leveling device is essentially the setting line of a VASI unit. Hence when a unit is adjusted by means of the device, the setting angle of the unit is the angle indicated on the scale of the device plus or minus 0.25°, depending on the position of the rotating section.

(5) The relations shown in table IV suggest that the glide path indicated by a VASI installation is approximately 0.5° above the setting indicated by the leveling device.

(6) The results obtained exhaust to a large extent the amount of information that can be obtained from the facilities available at the National Bureau of Standards. Therefore, if further study is required, it should be made at operational distances (of the order of miles) and with a complete VASI system in operation (to give the observers the benefit of a white or red reference light for their judgments.) This expanded study is beyond the scope of the National Bureau of Standards.

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